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for

DEVICE AND METHOD FOR DIGITIZING A SERIALIZED SCANNER OUTPUT SIGNAL

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DEVICE AND METHOD FOR DIGITIZING A SERIALIZED SCANNER OUTPUT SIGNAL

BACKGROUND

[1] The present invention relates generally to controlling an analog-front-end/digitizer having a plurality of color-signal-processing channels. The invention further relates to controlling the analog-front-end/digitizer such that each color component of a serial-analog-color signal generated by a contact image-sensor scan head is individually processed by a respective gain/offset channel

[2] **FIG. 1** illustrates certain components of a conventional scanner ***10***. The scanner ***10*** can be part of a copier or a device used for digitizing images for use with a personal computer. The scanner ***10*** typically includes a glass platen ***14*** on which a source image ***12***, such as a document or photograph, is placed for scanning. The scan head ***20*** typically includes a white light ***22*** for illuminating the source image ***12***, and is moved relative to the source image in a direction ***16***. The scan head ***20*** also includes a relatively small, *i.e.*, perhaps one inch by one inch, charged coupled device (hereafter CCD) ***28***, which captures an image of the source image ***12***. A lens ***26*** and an optical path ***23*** reduce the size of an image of the source image ***12***, which may be 8½-inches wide where the source image is a standard size sheet of paper, down to a size capturable by the CCD ***28***. An optical path of at least one foot is usually required for this. Therefore, the scan head ***20*** includes a plurality of mirrors, illustrated as mirrors ***24a-24c***, so the path ***23*** does not have to be a linear foot but can be "folded down" to a shorter or compact overall dimension. The last mirror ***24c*** reflects the image onto the lens ***26***, which focuses it on the CCD ***28***. The scan head ***20***, however, may have more than one lens, and more or fewer than three mirrors. Furthermore, for color images, the scan head ***20*** usually includes three paths ***23***, one for a red (***23R***), one for green (***23G***), and one for blue (***23B***). Portions of these paths ***23R***, ***23G***, and ***23B*** are shown in **FIG. 1**.

[3] For a color scanner ***10***, the CCD ***28*** typically has an array of three rows of sensors, one each for red (***28R***), green (***28G***), and blue (***28B***) (not shown). For an 8.5-inch wide, 600 dpi sensor, there are 5100 sensors in each row, for 16,300 sensors total. These arrays continuously and simultaneously capture the red, green,

and blue components of the image being copied as the scan head ***20*** moves in direction ***16*** relative to the source image ***12***. Therefore, the CCD ***28*** continuously and simultaneously outputs parallel red, green, and blue analog image signals for processing into a digital representation of the source image ***12***.

[4] **FIG. 2** is a schematic block diagram of a conventional multiple-channel image processing-system ***40*** that scans images for display and use in a personal computer ***46***. the system ***40*** includes the scan head ***20*** of the scanner ***10*** of **FIG. 1**, and further includes paper sensors ***19***, a motor driver ***17***, and a motor ***18*** that moves the scan head ***20*** relative to the source image ***12*** (**FIG. 1**) being scanned. The system ***40*** also illustrates an analog front end/digitizer ***42*** (also referred to as "AFE ***42***"), a scanner controller ***44***, and a memory ***48***.

[5] The AFE ***42*** is known in the prior art, and includes three input channels, one each for the red, green, and blue color components of the parallel-analog signal generated by the CCD ***28***. Each input channel includes a respective connector ***51***, a programmable offset DAC ***58***, a SUM ***52***, a programmable gain amplifier ***54***, and a register ***56***. While separate registers are shown for each channel, a single register common to all three channels may be used. The outputs of each channel are coupled to a 3:1 multiplexer ***60***, and the multiplexer ***60*** is coupled to an analog-to-digital converter ***62***. A digital-control interface module ***64*** is coupled to the 3:1 multiplexer ***60***, the register ***56***, and, optionally, other components of the AFE ***42***. The interface ***64*** is configured for coupling components of the AFE ***42*** with devices such as the controller ***44***.

[6] The controller ***44*** is typically an application-specific integrated circuit that includes functionality to operate the scanner ***10*** of **FIG. 1**, including the scan head ***20***, the AFE ***42***, and to interface with the personal computer ***46***. A memory ***48*** provides memory services to the controller ***44***, and may be any type of addressable storage device.

[7] In use, each color-component signal generated by the sensors of CCD ***28*** is initially calibrated to optimize the amplitude and determine the offset. The calibration includes adjusting the amplitude of each color-component signal to use the full input range of the ADC ***62***. This maximizes the signal to noise ratio. For

example, the Blue Analog Vout from the blue sensor ***28B*** might have only one-half the amplitude of the Red Analog Vout from the red sensor ***28R***. The calibration process determines what gain is necessary for each color-component signal so that all the color-component signals will have substantially the same amplitude, and will use the full number of available bits provided by the ADC ***62***. Values that set the amplifiers ***54*** to the necessary gains are stored in the respective register ***56*** for each color component. Likewise, the calibration process determines the offset or dark correction necessary for each color-component analog signal, and values that set the DACs ***58*** to the necessary offset are stored in the respective register ***56*** for each color component.

[8] Once scanning begins, the red, green, and blue sensors of the CCD ***28*** in response to a reflection of the white light from the source image ***12*** produce respective continuous and simultaneous parallel analog-color signals shown as Analog Vout in **FIG. 2**. The parallel Analog Vout signals are coupled respectively to the AFE ***42*** at connectors ***51R***, ***51G***, and ***51B*** over lines ***53R***, ***53G***, and ***53B*** into their respective color-component channels. The AFE ***42*** processes the parallel analog-color signals in their respective channels by simultaneously sampling each red, green, and blue color-component signals shown as Red Analog Vout, Blue Analog Vout, and Green Analog Vout from the sensors ***28R***, ***28B***, and ***28G***. The DAC ***58*** level shifts each color-component signal by the offset value stored in the register ***56***. Then, the PGAs ***54R***, ***54B***, and ***54G*** respectively scale each color-component signal by the gain value stored in the register ***56***. At this point, each color component of the parallel analog-color signal has been individually processed in its channel. The three processed color signals from the three programmable gain amplifiers ***54R***, ***54G***, and ***54B*** are then multiplexed through the 3:1 multiplexer ***60***, which sequentially samples the three processed color signals and generates a single analog signal that is provided to the ADC ***62***. The ADC ***62*** converts the single analog signal into a digital ADC data signal. The ADC data signal presents a single pixel at a time, and sequentially presents three colors for a single pixel column but not for a single pixel. The reason that the ADC data signal does not present three colors for a single pixel is that the physical separation of the three rows of the sensors ***28R***, ***28G***, and ***28B*** makes the colors physically separated on the page. For

example, if the red scan is from row 1, the green scan will be from row 5 and the blue scan will be from row 9 - all the same pixel column number. The data (COLORrow-column) from the ADC ***62*** looks like:

R1-1, G5-1, B9-1, R1-2, G5-2, B9-2, ... R1-5100, G5-5100, B9-5100

R2-1, G6-1, B10-1, R2-2, G6-2, B10-2, ... R2-5100, G6-5100, B10-5100

. . . .

The ADC data signal is provided to the controller ***44***, which exposes the ADC data signal to the personal computer ***46***.

[9] For example, red light reflected from a source image ***12*** (of **FIG. 1**) is sensed by the red senor ***28R***, which generates the Red Analog Vout signal. The Red Analog Vout signal is connected by line ***53R*** to terminal ***51R*** of the AFE ***42***, where it is then connected to SUM ***52R***. At SUM ***52R***, Red Analog Vout signal is level shifted or offset by the previously calibrated red offset stored in the Red Register ***56R***, and the offset Red Analog Vout signal is then scaled by the PGA ***54R*** by the previously calibrated gain. The offset and scaled Red Analog Vout signal is multiplexed through the 3:1 MUX ***60*** along with the green and blue offset and scaled signals and digitized by the ADC ***62***.

[10] **FIG. 3** illustrates certain components of a conventional scanner ***70*** that is similar to the scanner ***10*** except it includes a contact-image sensor (CIS) scan head ***72***. The CIS scan head ***72*** differs from the scan head ***20*** of **FIG. 1** in that the CIS scan head is much more compact and, therefore allows the scanner ***70*** to be smaller than scanner ***10***. The scan head ***72*** is more compact because it does not require the optical path ***23***, the mirrors ***24***, or focusing provided by the lens ***26*** of **FIG. 1**. The scan head ***72*** has the width of the maximum source image ***12***, and is placed in close proximity with the glass platen ***14***. For example, to copy or scan an 8½-by 11 sheet of paper, the copier or scanner would include a scan head ***72*** that is 8 ½ inches wide.

[11] The scan head ***72*** is in close proximity to the glass platen ***14***, and typically uses an array ***74*** of red, green, and blue light sources across the scan head ***72*** to provide a full spectrum of light to illuminate the source image ***12***. The light source typically include light emitting diodes (LED). There are two main types of

illumination based on LEDs. One style includes LEDs placed across the whole width of the scan head ***72***, and another style includes a few (even a single per color) LEDs on the side of the scan head and a plastic wave guide or light pipe is used to distribute the light across the width of the scan head. A lens ***76*** is positioned between the light reflected from the source image ***12*** and the CCD sensor ***78***.. A single row of sensors comprise the CCD sensor ***78***. The single row of sensors is distributed across the scan head ***72*** to receive light reflected from the source image ***12*** after being focused by the lens ***76***. In an 8.5-inch wide 600 dpi sensor, there are 5100 sensors in the single row. While the scan head ***20*** of **FIGS. 1** and **2** uses a single white light source ***22*** and three different CCD sensors ***28R***, ***28G***, and ***28B*** on a small chip to capture the color components of the source image ***12***, the CIS scan head ***70*** uses three different colored light-source arrays ***74R***, ***74G***, and ***74B***, and a single CCD sensor ***78*** both distributed across a width of the scanned source image ***12*** to capture all three color components.

[12] To scan the source image ***12***, for example, first the red-light source(s) ***74R*** are flashed across the width of the source image ***12*** to illuminate a line of the source image and provide the red components of the image. Then, the green-light source(s) ***74G*** are flashed to provide the green components, and then blue-light source(s) ***74B*** are flashed to provide the blue components. During each light flash, light reflected from the source image ***12*** is focused by the lens ***76*** onto the CCD sensor ***78***, which captures the color component of the image and outputs a representation analog signal. Each color light source ***74*** is sequentially flashed once for each line and the CCD sensor ***78*** serially generates the analog color signals in the sequence that the lights are flashed, in this example red, green, and blue. This cycle continues such that the red, green, and blue components of each line of the source image ***12*** are scanned. Although the scan head ***72***, with its light array ***74*** and CCD sensor ***78***, may move step-by-step so as to scan one line three times, once each for the RGB color components, it is more common for the scan head ***72*** to move at a constant velocity such that the red, green, and blue components are each scanned for one of three overlapping lines. Since the constant velocity allows every 3rd scan to be a new line (every 3rd scan is the same color), the scanner has only moved or stepped 1/3 of an overlapping line for each color scan. Therefore, the

three scanned colors are overlapping. For each line sampled by the CCD scanner ***10*** of **FIG. 1**, the CIS scanner ***70*** of **FIG. 3** will scan three overlapping lines. With an equal number of sensors in each row, the resolution of the CCD and CIS type scanners is the same.

[13] The analog signal produced by the CCD sensor ***78*** of the CIS scanner ***70*** as it scans RGB color components serially is referred to herein as a serial analog-color signal. The serial analog-color signal contrasts with the three channel analog signal provided by the three rows of sensors of the CCD ***28*** of the scanner ***10*** of **FIG. 1**, which generates the three-color components in parallel on three parallel conductors. Commonly available analog front end/digitizers, such as the AFE ***42*** illustrated in **FIG. 2**, do not readily provide a circuit or method for individually processing each color component of a serial-analog signal generated by a CIS scan head ***72*** to adjust offset and gain. One proposed compromise solution is to couple the CCD sensor ***78*** to one channel of a commonly available AFE, such as to the red channel at connection ***51R*** of the AFE ***42*** of **FIG. 2**, and establish a single-offset value and a single-gain value. The single values would be applied to all three colors. The proposed solution is not adequate because the single values do not take into account a potential for significant variation in the red, green, and blue color-component signals generated by the CCD sensor ***78***.

SUMMARY

[14] In view of the foregoing, there is a need for a new and improved apparatus and method for individually processing each color component of an analog signal where the signal may have a parallel mode or a serial mode. The present invention is directed to a device, system, and method that provide such an improved apparatus and method for individually processing each color component of a serial-analog signal.

[15] One embodiment of the invention provides a device for individually processing each color component of a serial-analog signal from a color scanner. The device includes a multiple-channel image-capture circuit comprising an analog front end/digitizer having a plurality of channels operable to process an analog-color signal with one channel for each color component of the analog-color signal, a

register, and an analog-to-digital converter operable to output a digital signal responsive to the analog-color signal, and a controller operable to control the color-component processing by the plurality of input channels such that each color component of a serial analog-color signal is individually processed. Each input channel of the analog front end/digitizer may include a programmable circuit operable to modify a color component of the color signal in response to a value stored in the register related to the color component.

[16] Such a device allows a serial analog-color signal from a scanner with a contact-image sensor to be individually processed for each color component.

[17] These and various other features as well as advantages of the present invention will be apparent from a reading of the following detailed description and a review of the associated drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[18] Features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may best be understood by making reference to the following description taken in conjunction with the accompanying drawings, in the several figures of which like referenced numerals identify like elements, and wherein:

[19] **FIG. 1** illustrates certain components of a conventional scanner;

[20] **FIG. 2** is a schematic block diagram of a conventional multiple-channel image-processing system that scans images for display and use in a personal computer;

[21] **FIG. 3** illustrates certain components of a conventional scanner having a contact-image sensor scan head; and

[22] **FIG. 4** is a schematic block diagram of a multiple-channel image-processing system for a scanner using a CIS scan head in accordance with an embodiment of the invention.

Detailed Description

[23] In the following detailed description of exemplary embodiments of the invention, reference is made to the accompanying drawings, which form a part hereof. The detailed description and the drawings illustrate specific exemplary embodiments by which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. It is understood that other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the present invention. The following detailed description is therefore not to be taken in a limiting sense.

[24] **FIG. 4** is a schematic block diagram of a multiple-channel image-processing system ***90*** for a scanner using a CIS scan head ***72***, in accordance with an embodiment of the invention. The system ***90*** illustrates components of the scanner ***70*** of **FIG. 3**, including the CIS scan head ***72***, and the paper sensors ***19***, the motor driver ***17***, and the motor ***18*** that moves the scan head ***72*** relative to the source image ***12*** being scanned. The system ***90*** also illustrates the analog front end/digitizer ***42*** (also referred to as "AFE ***42***"), a scanner controller ***80***, and the memory ***48***. Except for the CIS scan head ***72*** and the scanner controller ***80***, the components of the system ***90*** are substantially similar to the system ***40*** of **FIG. 2**.

[25] Because the CIS scan head ***72*** only has one CCD sensor ***78***, only a single Analog Vout signal is generated. In the embodiment illustrated, a single line ***93*** carries the serial analog-color signal Analog Vout from the CIS scan head ***72*** to the AFE ***42***. The line ***93*** is connected to the connectors ***51R***, ***51G***, and ***51B*** in parallel, providing the signal to the three input channels of the AFE ***42***. The controller ***80*** is operable to control the color-component processing by the plurality of input channels such that each color component of the Analog Vout signal is individually processed. The controller ***80*** is further operable to control the CIS scan head ***72*** that produces the serial-analog-color signal. Even though the CIS scan head ***72*** uses the same sensors for each color, the illumination source (LED ***74***) is not ideal and it is necessary to compensate for each color separately. The overall illumination intensity of each light source in the LED ***74*** is unique and requires a different gain setting for each illuminant color. In addition, the CCD sensor ***78*** has

some sensitivity to the wavelength of the illumination that must be compensated for. Best results are provided with a unique analog gain and offset for each RGB color.

[26] The functions of the scanner controller ***80*** may be implemented in hardware such as interconnected machine-logic circuits or circuit modules, firmware, in special purpose digital logic, software, or a combination thereof without deviating from the spirit or scope of the present invention. The implementation is a matter of choice dependent on the performance requirements of the system ***90*** implementing the invention. Implementation in hardware is a more preferred embodiment.

[27] Operation will be illustrated first by the scanning the red color component. As before, each channel is calibrated for a respective color. The channel coupled to connector ***51R*** is calibrated for red (red channel), the channel coupled to connector ***51G*** is calibrated for green (green channel), and the channel coupled to connector ***51B*** is calibrated for blue (blue channel). The controller ***80*** flashes the red light source ***74R*** (**FIG 3**). The single CCD sensor ***78*** generates an analog signal that represents only the red illuminated color component of a line of the source image ***12***. That signal, Analog Vout, is provided to all three channels of the AFE ***42*** at connectors ***51R***, ***51G***, and ***51B***. Each channel processes the red color component according to values stored in the respective register ***58*** for the color calibrated for that channel even though the signal Analog Vout includes only the red color component. The controller ***80***, through the digital interface ***64***, controls the 3:1 MUX ***60*** to sample only the processed red color component from the red channel. The other processed signals from the blue and green channels are ignored. The processed and sampled red color analog signal is provided to the ADC ***62***, which generates the ADC data out signal representing the red color component of one line of the source image ***12***.

[28] Next, the scan head ***72*** is advanced one line. The controller ***80*** flashes the green light source ***74G***. The CCD sensor ***78*** outputs a responsive analog signal Analog Vout representing only the green illuminated color component of the source image ***12***. That signal is provided to all three channels, the green channel coupled to connector ***51G*** being the only channel calibrated for processing green. Each channel processes the green color component according to values stored in the respective register ***58*** for the color calibrated for that channel even though the signal

Analog Vout includes just the green color component. The controller ***80***, through the digital interface ***64***, controls the 3:1 MUX ***60*** to sample only the processed green color component from the green channel. The other processed signals from the red and blue channels are ignored. The processed and sampled green color analog signal is provided to the ADC ***62***, which generates the ADC data out signal representing the green color component of this line of the source image ***12***.

[29] The controller ***80*** performs the same process for the blue color, completing the scanning and digitizing of RGB color data in three lines, one for each RGB color. The resolution of the conventional CCD scanner ***10*** of **FIG. 1** and the CIS scanner ***70*** of **FIGS. 3** and 4 is substantially the same. The CIS scanner ***70*** scans three overlapping lines for each line the CCD scanner ***10*** scans, but since the CIS scanner only includes data for one color for each overlapping line and the CCD scanner ***10*** includes RGB color data for each line, the ultimate resolution is the same.

[30] The ADC data signal still only presents a single pixel at a time as with the CCD scanner ***10*** of **FIG 1**. However, for the CIS scanner ***70*** of **FIG. 3**, the ADC data signal serially presents the three colors one line at a time. The ADC data signal (COLORrow-column) from the CIS scanner ***70*** looks like:

R1-1, R1-2, ... R1-5100, G1-1, G1-2, ... G1-5100, B1-1, B1-2, ... B1-5100

R2-1, R2-2, ... R2-5100, G2-1, G2-2, ... G2-5100, B2-1, B2-2, ... B2-5100

. . . .

[31] The controller ***80*** includes a Direct Memory Accesses (DMA) controller (not shown) to which the serialized ADC data signal from the AFE ***42*** is passed. The DMA controller of the controller ***80*** unscrambles the AFE data signal and puts it into memory in single color blocks of data. The controller ***80*** is configured to handle the ADC data signal from either a CIS or CCD type scanner. The data ends up in three separate blocks of memory for each pixel: a block of just the red, a block of green and a block of blue data. The DMA is operable to handle the two different serial streams of data and separate each color and store it in memory appropriately. Firmware in the controller ***80*** configures the memory block to match type of scanner being controlled.

[32] Still referring to **FIG. 4**, an alternative embodiment of the system ***90*** uses only one selected channel of the AFE ***42*** to process all the color components of the serial analog signal Analog Vout. The values stored in the register ***56*** of the selected channel are changed to the calibrated value for the color component being processed. For example, the single line ***93*** carrying the Analog Vout signal from the CIS scan head ***72*** can be coupled to the connector ***51R*** for processing of all color components by the first channel (shown in **FIG 4** as the channel assigned to processing the red signal). Red is processed by the red channel, sampled by the 3:1 MUX ***60***, and provided to the ADC ***62*** as described above, which generates the ADC data out signal representing the red color component of this line of the source image ***12***. Prior to processing green Analog Vout signal in the red channel, the controller ***80***, acting through the digital interface ***64***, changes the calibration values in the first register ***56R*** to the calibration values associated with green. The calibration values may be stored in the register ***58***, or alternatively, the values may be stored in a memory coupled to the controller ***80***, such as the memory ***48***. The controller ***80*** flashes the green colored light source ***74G***, and the Analog Vout is provided to the first channel at input ***51R***, where it is processed according to calibration values then currently stored in the register ***54R***, which are the calibration values for the green color component. The process is repeated for blue, completing the scanning and digitizing of the serial analog-color signal. The MUX ***60*** is configured only to sample the signal from the red channel, and does not switch between the channels as in the previously discussed embodiment.

[33] In another embodiment, the controller ***80*** is operable to control the color component processing for both a serial analog-color signal and a parallel analog-color signal. This embodiment will allow a single AFE ***42*** and controller ***80*** pair to process a scan head analog-color-signal output without regard to whether the signal is serialized or parallel. In a further embodiment, the system ***90*** includes a switch (not illustrated) operable to switch between a plurality of parallel inputs with each input being coupled to one processing channel, a single serial signal input coupled to all processing channels, and a single serial input coupled to one processing channel. The switch may include any structure, such as mechanical or transistor device, or may simply provide alternative positions for hardwiring.

[34] Although the present invention has been described in considerable detail with reference to certain preferred embodiments, other embodiments are possible. Therefore, the spirit or scope of the appended claims should not be limited to the description of the embodiments contained herein. It is intended that the invention resides in the claims hereinafter appended.